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Impact of foliar application of growth regulators on fruit splitting, yield and quality of daisy mandarin (*Citrus reticulata*)

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ABSTRACT

The experiment was conducted during 2021 and 2022 at the Fruit Research Station, Jallowal-Lesriwal, Jalandhar (Punjab Agricultural University), Punjab to study the effect of foliar application of growth regulators on fruit splitting, yield and quality of Daisy mandarin (*Citrus reticulata* Blanco). The different concentrations of gibberellic acid (GA_3) (10, 20 and 30 ppm), naphthalene acetic acid (NAA) (10, 20 and 30 ppm), ethephon (10, 20 and 30 ppm) and salicylic acid (SA) (100 and 200 ppm) along with control were applied at different developmental stages of Daisy mandarin. The results revealed that the application of salicylic acid at 100 ppm effectively mitigated the severity of fruit splitting in Daisy mandarin during both the seasons and highest fruit weight, number of fruits and maximum fruit yield were observed with foliar application of GA_3 at 10 ppm. Regarding the fruit quality attributes including total soluble solids, ascorbic acid, juice and flavonoid content, exhibited superior results with the application of 10 ppm GA_3 as compared to untreated plants. The results suggested that application of 10 ppm GA_3 and 100 ppm salicylic was effective in enhancing fruit quality attributes and reducing the incidence of fruit splitting in Daisy mandarin.

Keywords: Daisy, Foliar application, Fruit cracking, Gibberellic acid, Plant growth regulators, Salicylic acid

Daisy mandarin (*Citrus reticulata* Blanco) is cross between Fremont and Fortune mandarins developed by Mr. Dowling Young of Young's Nursery in California, USA. It was found promising considering its early maturity and high fruit quality (Gill *et al*. 2017) and introduced from USA, in Punjab to diversify the Kinnow which is a leading mandarin in Punjab occupies more than 50% of total area under fruits. The total area and production of citrus in Punjab during 2021 was 50.19 thousand ha with 1.22 Mt production (Anonymous 2021). Another major aspect for introducing this fruit was to increase the market period of mandarin in Punjab from November to February (Dhillon *et al.* 2016). Daisy mandarin faces so many constraints throughout its growth, but the primary issue is fruit splitting. Fruit splitting represent a prevalent pre-harvest physiological anomaly that affects various fruit crops, leading to reduced production and quality of fruit crops. When mature fruit cracks or splits, it becomes more susceptible to infection by pathogens and loses water, which negatively impacts its appearance and shelf life (Yu *et al.* 2020). Fruit splitting occurs at a rate of 10–35%, which has an adverse effect on fruit quality and yield of citrus**.**

Fruit splitting can be significantly reduced by optimizing growing conditions such as improved cultural practices, adequate supply of water and foliar applications of growth regulators. Plant growth regulators such as Salicylic acid (SA), Gibberellic acid (GA_3) and Naphthalene acetic acid (NAA), serve as signaling molecules with a vital role in modulating growth and enhancing plant resilience in the presence of both abiotic and biotic stresses. Growth regulators play an essential role in influencing the peel resistance and flexibility, which ultimately dictate the extent of cracking. Singh *et al*. (2006), suggested that the systematic spraying of PGRs before the rind splitting could aid to control cracking by influencing rind thickness. In addition to mitigating the incidence of fruit splitting, foliar application of growth regulators demonstrated a noteworthy augmentation in yield and quality of Daisy mandarin. The primary aim of this study was to assess the impact of plant growth regulators on the mitigation of fruit splitting, as well as the augmentation of yield and the improvement of quality attributes in the Daisy mandarin.

MATERIALS AND METHODS

The present study was carried out during 2021 and 2022 at Fruit Research Station, Jallowal-Lesriwal, Jalandhar (31° 29′ 38" N and 75° 37′ 40" E and 228 m amsl) (Punjab Agricultural University), Punjab. The soil type of the plot

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was characterized as sandy loamy. The experiment was laid out on 8 years old Daisy mandarin plants, which were planted with a spacing of 6×3 m^2 and were budded on rough lemon rootstock. All of the agronomical practices including irrigation, fertilization, manuring and plant protection measures were adhered strictly to the recommendations established by Punjab Agricultural University, package of practices for fruit crops. The treatments encompassed of the following concentrations: 10, 20, 30 ppm GA_3; 10, 20, 30 ppm NAA; 10, 20, 30 ppm Ethephon; 100, 200 ppm SA and control. GA_3 and NAA were applied through foliar spraying at the stages of fruit set, 30 days after fruit set (DAFS) and 60 DAFS, whereas ethephon was also applied at 30 DAFS and 60 DAFS. Salicylic acid was sprayed at the initiation of fruit splitting.

The experiment followed a randomized block design (RBD) with 3 replications per treatment. Number of fruits on the tree was counted from the 90 DAFS until the harvest (210 DAFS), during both the years 2021 and 2022. The number of splitted fruits were counted periodically at monthly interval. Fruit splitting was estimated by counting the number of splitted fruits divided by total number of fruits. Average fruit weight of Daisy mandarin plants was taken by using an electronic weighing balance with an accuracy of 0.01/g (EK6100I A&D, Japan). The yield/plant was determined by multiplying the average fruit weight to the total number of fruits produced/plant, and the result was expressed in kilogram (kg).

TSS of the fruit juice was measured by using digital hand refractometer (ATAGO, PAL-1, Japan) with a range of 0–53°Brix. Acidity, ascorbic acid and juice content were measured by using the standard procedures of AOAC (2005). The Folin-ciocalteau reagent method purposed by Malik and Malik (1982) was used to determine the flavonoids content from the fruit juice of Daisy mandarin plants. The data were examined by using the SAS package from SAS Institute Inc. (version 93, USA). To compare the variations in treatment means, the least significant difference method was employed as a post hoc analysis.

RESULTS AND DISCUSSION

Fruit splitting severity (%): The application of plant growth regulators was observed to exert a notable effect on the occurrence of fruit splitting severity of Daisy mandarin budded on rough lemon rootstock. Maximum fruit splitting (13.25%) was recorded in untreated plants as compared to treated plants (Table 1). Out of the various growth regulators, the lowest incidence of fruit splitting was recorded with foliar application of SA at 100 ppm (3.14%), followed by SA at 200 ppm (3.41%), GA_3 at 10 ppm (4.87%) during

Table 1 Effect of foliar application of growth regulators on fruit splitting severity of Daisy mandarin

Treatment	90 (DAFS)		120 (DAFS)		150 (DAFS)		180 (DAFS)		210 (DAFS)		Total fruit splitting (%)
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	
10 ppm GA_3	1.79 ± 0.18^{b}	2.11 ± 0.37^{bcd}	1.14 ± 0.20^{cd}	1.37 ± 0.32^{c}	0.99 ± 0.15^{b}	1.12 ± 0.16^{b}	0.39 ± 0.16^{b}	0.48 ± 0.19^{bc}	0.18 ± 0.07^{b}	0.20 ± 0.08^{bc}	4.87
20 ppm GA_3	1.83 ± 0.26^{b}	2.39 ± 0.13^{bcd}	1.34 ± 0.17^{bc}	1.53 ± 0.21^{bc}	1.03 ± 0.17^{b}	1.27 ± 0.01^{b}	0.57 ± 0.02^{b}	0.63 ± 0.01^{b}	0.20 ± 0.08^{b}	0.22 ± 0.09^{bc}	5.51
30 ppm GA_3	1.94 ± 0.26^{b}	2.54 ± 0.52^{bcd}	1.43 ± 0.15^{bc}	1.57 ± 0.20^{bc}	1.12 ± 0.18^{b}	1.34 ± 0.01^{b}	0.60 ± 0.01^{b}	0.65 ± 0.01^{b}	0.22 ± 0.09^{b}	0.28 ± 0.11^{bc}	5.84
10 ppm NAA	1.91 ± 0.31^{b}	2.49 ± 0.21^{bcd}	1.34 ± 0.17^{bc}	1.56 ± 0.18^{bc}	1.06 ± 0.18^{b}	1.34 ± 0.01^{b}	0.60 ± 0.02^{b}	0.63 ± 0.00^{b}	0.20 ± 0.08^{b}	0.26 ± 0.11^{bc}	5.69
20 ppm NAA	1.79 ± 0.20^{b}	2.33 ± 0.41^{bcd}	1.31 ± 0.03^{bc}	1.43 ± 0.18^{bc}	1.01 ± 0.15^{b}	1.23 ± 0.01^{b}	0.42 ± 0.17^{b}	0.61 ± 0.00^{b}	0.19 ± 0.08^{b}	0.22 ± 0.09^{bc}	5.27
30 ppm NAA	1.99 ± 0.12^{b}	2.56 ± 0.27^{bcd}	1.60 ± 0.18^{bc}	1.79 ± 0.033^{bc}	1.12 ± 0.19^{b}	1.42 ± 0.18^{b}	0.65 ± 0.02^{b}	0.67 ± 0.00^{b}	0.23 ± 0.09^{b}	0.28 ± 0.12^{bc}	6.16
10 ppm Ethephon	2.04 ± 0.03^{b}	2.67 ± 0.22^{bc}	1.63 ± 0.16^{bc}	1.91 ± 0.023^{bc}	1.25 ± 0.27^{b}	1.47 ± 0.14^{b}	0.67 ± 0.00^{b}	0.69 ± 0.01^{b}	0.25 ± 0.10^{b}	0.30 ± 0.12^{bc}	6.44
20 ppm Ethephon	2.06 ± 0.44^{b}	2.78 ± 0.06^{b}	1.90 ± 0.31^{bc}	2.03 ± 0.16^{bc}	1.31 ± 0.30^{b}	1.53 ± 0.21^{b}	0.68 ± 0.13^{b}	0.80 ± 0.15^{b}	0.32 ± 0.13^{b}	0.38 ± 0.15^{b}	6.89
30 ppm Ethephon	2.12 ± 0.17^{b}	2.83 ± 0.36^{b}	1.91 ± 0.31^{b}	2.11 ± 0.20^{b}	1.36 ± 0.02^{b}	1.59 ± 0.21^{b}	0.71 ± 0.29^{b}	0.88 ± 0.17^{b}	0.36 ± 0.14^{b}	0.42 ± 0.17^{b}	7.15
100 ppm SA	2.49 ± 0.04^{b}	2.56 ± 0.0^{d}	0.68 ± 0.02^{c}	0.55 ± 0.02^{e}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0 ± 0.00^{b}	0 ± 0.00^{c}	3.14
200 ppm SA	2.60 ± 0.01^{ab}	2.77 ± 0.02^{b}	0.74 ± 0.02^{d}	0.73 ± 0.02^{de}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0.0 ± 0.00^{c}	0 ± 0.00^{b}	0 ± 0.00^{c}	3.41
Control	3.34 ± 0.27^{a}	4.16 ± 0.33^{a}	3.55 ± 0.48^{a}	3.81 ± 0.27^{a}	2.56 ± 0.22^{a}	2.56 ± 0.22^{a}	2.34 ± 0.02^{a}	1.54 ± 0.38^{a}	1.27 ± 0.32^{a}	1.37 ± 0.28^{a}	13.25
Mean	2.16	2.68	1.55	1.70	1.06	1.24	0.63	0.63	0.28	0.33	6.12
CD (P<0.05)	0.83	1.01	0.76	0.68	0.59	0.51	0.38	0.53	0.39	0.37	

2021 and 2022 at 90 DAFS. Fruit splitting intensity was found highest at 90 DAFS than other days after fruit set. Application of antioxidants such as salicylic acid protects the plant cells by affectively inhibiting the accumulation of ROS and prevent from oxidative damage. Sharma *et al.* (2020), SA is a phenolic compound that influences the various aspects of plant physiology, which enhances photosynthesis, nutrient uptake and nutrient transport within the plant and biosynthesis of plant pigments. Abdel Aziz *et al.* (2017) noted a reduction in fruit splitting when salicylic acid was applied to pomegranate plants. Karantzi *et al.* (2021) observed similar results in fig, with application of SA wherein number of fruits without splitting increased.

Fruit weight, fruit size and number of fruits: The highest fruit weight (206.00 and 206.33 g) was observed when GA_3 was applied at a concentration of 10 ppm, closely followed by NAA at 20 ppm (199.00 and 205.67 g) and SA at 100 ppm (197.00 and 203.67 g) during years (2021 and 2022, respectively) (Table 2). Minimum fruit weight was recorded in untreated plants (183.67 and 184.67 g) during years (2021 and 2022, respectively). The increased fruit weight may be attributed due to hormonal regulation of transporting and accumulating photosynthates, which leads to fruit development. In addition to it, hormones may regulate the cell division, elongation and enlargement. Increased fruit weight with application of GA_3 was documented in Nagpur mandarin by Jain *et al.* (2014), while Debbarma and Hazarika (2016), reported similar results in acid lime. Application of synthetic auxins leads to increase the level of auxin within the fruits, due to this rise in auxin level, that promotes the development of different parts of fruits, because during fruit development, the developing fruits function as a reservoir where organic acids gradually accumulate, consequently contributing to an increase in the fruit weight. Similar findings were observed by Nawaz *et al.* (2011) in Kinnow mandarin. The foliar application of PGRs significantly increased the fruit size as compared to control. The maximum fruit length (6.88 and 6.83 cm) was recorded with the application of GA_3 10 ppm, followed by NAA 20 ppm (6.84 and 6.83 cm) during 2021 and 2022, respectively, while minimum (6.25 and 6.21 cm) fruit length was observed under control during both studied years. The application of 10 ppm GA_3 resulted in maximum fruit breadth (7.20 and 7.12 cm), followed by 20 ppm NAA (7.08 and 7.03 cm), while minimum fruit breadth was observed in control (6.62 and 6.58 cm) during 2021 and 2022, respectively. An increase in fruit size and shape of fruit due to growth regulators could be attributed to the fact that there is an

Table 2 Effect of foliar application of growth regulators on yield attributes of Daisy mandarin

Treatment	Fruit weight (g)		Fruit length (cm)		Fruit breadth (cm)		Number of fruits/ tree		Fruit yield/tree (kg/tree)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
10 ppm GA_3	206.00 ± 2.06^{a}	206.33 ± 1.19^{a}	6.88 ± 0.02^{a}	6.83 ± 0.04^{a}	7.20 ± 0.02^{a}	7.12 ± 0.01^{a}	168.67 ± 1.66^{a}	178.0 ± 2.16^{a}	34.74 ± 0.11^{a}	36.73 ± 0.65^{a}
20 ppm GA_3	190.67 ± 2.13^{bcd}	200.67 ± 1.66^{abc}	6.66 ± 0.03^{bc}	6.61 ± 0.02^{bc}	6.82 ± 0.02^{e}	6.80 ± 0.01^{cd}	160.33 ± 1.44^{b}	162.0 ± 2.36^{bc}	30.57 ± 0.57^{bc}	32.50 ± 0.39^{cd}
30 ppm GA_3	190.67 ± 1.44^{bcd}	195.00 ± 1.42^{bcd}	6.66 ± 0.02^{bc}	6.60 ± 0.03^{bc}	6.75 ± 0.01^{f}	6.74 ± 0.01^{de}	153.00 ± 2.16^{c}	159.3 ± 2.13^{bc}	29.16 ± 0.35^{cd}	31.08 ± 0.64^{cde}
10 ppm NAA	189.00 ± 2.16^{cd}	193.67 ± 0.72^{cd}	6.65 ± 0.02^{bc}	6.55 ± 0.03^{bc}	6.74 ± 0.02^{fg}	6.72 ± 0.02^{e}	152.00 ± 1.42^{cd}	159.0 ± 2.83^{bcd}	28.72 ± 0.25^{d}	30.80 ± 0.66^{def}
20 ppm NAA	199.00 ± 2.16^{ab}	205.67 ± 3.81^{a}	6.84 ± 0.05^{a}	6.83 ± 0.04^{a}	7.08 ± 0.01^{b}	7.03 ± 0.02^{b}	168.33 ± 1.66^{a}	174.0 ± 2.36^{a}	33.51 ± 0.69^{a}	35.79 ± 0.97^{ab}
30 ppm NAA	188.33 ± 1.44^{cd}	193.00 ± 1.89^{cde}	6.60 ± 0.01^{bc}	6.52 ± 0.03^{cd}	6.72 ± 0.02^{fgh}	6.64 ± 0.01^{f}	152.00 ± 1.42^{cd}	154.3 ± 2.38^{cde}	28.63 ± 0.48^{d}	29.79 ± 0.64^{ef}
10 ppm Ethephon	191.33 ± 1.19^{bcd}	201.00 ± 1.89^{abc}	6.67 ± 0.03^{b}	6.64 ± 0.03^{b}	6.88 ± 0.02^{d}	6.85 ± 0.01^{c}	160.67 ± 1.19^{b}	162.7 ± 1.91^{bc}	30.73 ± 0.04^{b}	32.69 ± 0.39^{cd}
20 ppm Ethephon	187.67 ± 1.44^{d}	192.33 ± 2.38^{cde}	6.57 ± 0.02^{c}	6.51 ± 0.03^{cd}	6.70 ± 0.01^{fgh}	6.63 ± 0.02^{f}	148.00 ± 1.42^{d}	153.0 ± 3.40^{de}	27.77 ± 0.07^{de}	29.45 ± 1.01^{ef}
30 ppm Ethephon	186.00 ± 2.63^{d}	191.67 ± 1.19^{de}	6.48 ± 0.02^{d}	6.42 ± 0.02^{de}	6.68 ± 0.02^{gh}	6.62 ± 0.02^{f}	142.00 ± 1.42^{e}	149.6 ± 2.38^{ef}	26.41 ± 0.37^{ef}	28.68 ± 0.44^{ef}
100 ppm Salicylic acid	197.00 ± 2.95^{abc}	203.67 ± 2.88^{ab}	6.80 ± 0.02^{a}	6.76 ± 0.04^{a}	7.02 ± 0.02^{c}	7.00 ± 0.02^{b}	161.00 ± 1.42^{b}	163.6 ± 2.38^{b}	31.72 ± 0.61^{b}	33.32 ± 0.35^{bc}
200 ppm Salicylic acid	185.67 ± 1.66^{d}	189.33 ± 1.66^{de}	6.48 ± 0.01^{d}	6.35 ± 0.03^{e}	6.66 ± 0.01^{hi}	6.60 ± 0.01^{f}	141.33 ± 0.98^{e}	149.6 ± 3.31^{ef}	26.24 ± 0.41^{f}	28.35 ± 0.88^{fg}
Control	183.67 ± 5.53^{d}	184.67 ± 4.82^{e}	6.25 ± 0.02^{e}	6.21 ± 0.01^{f}	6.62 ± 0.02^{i}	6.58 ± 0.02^{f}	140.67 ± 1.19^{e}	141.0 ± 0.94^{f}	25.82 ± 0.56^{f}	26.05 ± 0.82^{g}
Mean	191.25	196.42	6.62	6.57	6.82	6.78	154.00	158.86	30.27	31.27
CD (P<0.05)	9.28	8.70	0.09	0.11	0.05	0.06	4.53	8.99	2.36	2.48

increase in the number of cells during cell division and enlargement of cells at the later fruit development stages (Singh *et al*. 2017). Similar results were observed Habibi *et al*. (2021) in Thompson navel oranges.

The number of fruits were enhanced significantly with foliar application of growth regulators (Table 2). It was found that maximum number of fruits per plant was recorded with application of GA_3 at 10 ppm (168.67 and 178.0), followed NAA at 20 ppm (168.33 and 174.0). The control plants exhibited the lowest number of fruits per plants (140.67 and 141.0) during both seasons 2021 and 2022. The increase in number of fruits through the application of GA_3 and NAA could be attributed due to less dropping of flower and fruit shedding. This reduction in shedding may result from the use of growth regulators compensating for the deficiency of natural auxin, thereby preventing the formation of an abscission layer possibly by inhibiting the enzymatic activity at higher temperature (Sweety *et al.* 2018). Our results are in accordance with the results of Jagtap *et al.* (2013) for Kagzi lime.

The fruit yield was found to be significantly higher (37.74 and 36.73 kg/tree) in both the years 2021 and 2022, respectively with GA_3 at 10 ppm, as compared to the other treatments, whereas the minimum fruit yield was noticed in untreated plants (25.82 and 26.05 kg/tree) respectively during both the studied seasons. The fruit yield resulted from the application of GA_3 and NAA treatments could be attributed due to the fact that partioning of assimilates of GA_3 more towards the fruit development, coupled with better translocation of assimilates, which further leads to yield related attributes such as fruit size and weight, ultimately increased the yield (Khalid *et al.* 2012). Similar results were observed by Choudhary *et al.* (2013) and Abdel Aziz *et al.* (2017) in Nagpur mandarin and pomegranate fruits, respectively.

Fruit quality attributes: Total soluble solids measurements are important quality parameters of citrus fruits. It was found that maximum TSS was recorded with application of GA_3 at 10 ppm (11.28 and 11.23°Brix), followed by NAA at 20 ppm (11.25 and 11.09°Brix) during 2021 and 2022, respectively (Table 3). The TSS was found to be significantly lower in control plants (10.46 and 10.43°Brix) during 2021 and 2022. The increase in TSS content in juice resulting from the foliar application of GA_3, NAA could be due to enzymatic conversion of complex carbohydrates into simple sugars (Rub *et al.* 2010)

Table 3 Effect of foliar application of growth regulators on TSS, titratable acidity and ascorbic acid, juice content and flavonoids content of Daisy mandarin

Treatment	TSS (°Brix)		Titratable acidity (%)		Ascorbic acid (mg/100 ml)		Juice comntent (%)		Flavonoid content (mg RE/g FW)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
10 ppm GA_3	11.28 ± 0.02[a]	11.23 ± 0.02[a]	0.65 ± 0.01[c]	0.66 ± 0.00[e]	26.06 ± 0.03[a]	25.83 ± 0.04[a]	50.58 ± 0.43[a]	49.66 ± 2.02[a]	3.93 ± 0.02[a]	3.91 ± 0.18[a]
20 ppm GA_3	11.03 ± 0.02[cd]	11.03 ± 0.02[b]	0.68 ± 0.00[ab]	0.67 ± 0.00[bcde]	25.71 ± 0.04[bc]	24.74 ± 0.02[c]	47.57 ± 0.45[bc]	47.19 ± 0.71[a]	3.79 ± 0.01[bcd]	3.65 ± 0.15[ab]
30 ppm GA_3	10.99 ± 0.02[de]	11.01 ± 0.01[bc]	0.68 ± 0.00[bc]	0.68 ± 0.00[bcde]	25.66 ± 0.03[bc]	24.74 ± 0.02[c]	47.57 ± 0.38[bc]	46.95 ± 0.71[ab]	3.75 ± 0.02[cde]	3.57 ± 0.42[ab]
10 ppm NAA	10.99 ± 0.02[de]	10.99 ± 0.01[c]	0.69 ± 0.01[ab]	0.68 ± 0.01[bcde]	25.65 ± 0.04[bc]	24.74 ± 0.03[c]	46.85 ± 0.83[bc]	46.93 ± 1.89[ab]	3.74 ± 0.01[def]	3.52 ± 0.21[ab]
20 ppm NAA	11.25 ± 0.02[ab]	11.09 ± 0.02[b]	0.67 ± 0.01[bc]	0.66 ± 0.00[de]	26.03 ± 0.02[a]	25.78 ± 0.03[ab]	50.29 ± 1.37[a]	48.42 ± 3.41[a]	3.85 ± 0.01[b]	3.78 ± 0.27[ab]
30 ppm NAA	10.96 ± 0.03[de]	10.98 ± 0.04[cd]	0.69 ± 0.01[ab]	0.69 ± 0.00[bcd]	25.64 ± 0.22[bc]	24.74 ± 0.02[c]	46.72 ± 0.47[bc]	45.52 ± 0.98[ab]	3.69 ± 0.01[efg]	3.31 ± 0.42[ab]
10 ppm Ethephon	11.08 ± 0.02[c]	11.05 ± 0.01[a]	0.68 ± 0.07[abc]	0.67 ± 0.00[cde]	25.82 ± 0.03[ab]	24.75 ± 0.03[c]	47.70 ± 0.35[bc]	47.66 ± 1.33[a]	3.81 ± 0.01[bcd]	3.65 ± 0.18[ab]
20 ppm Ethephon	10.94 ± 0.02[e]	10.97 ± 0.04[cd]	0.69 ± 0.00[ab]	0.69 ± 0.00[bcd]	25.50 ± 0.08[cd]	24.53 ± 0.04[d]	46.65 ± 0.56[bc]	45.29 ± 0.70[ab]	3.68 ± 0.04[fg]	3.31 ± 0.33[ab]
30 ppm Ethephon	10.82 ± 0.04[f]	10.88 ± 0.04[d]	0.70 ± 0.00[ab]	0.69 ± 0.01[bc]	24.96 ± 0.05[e]	23.74 ± 0.02[e]	46.27 ± 0.51[bcd]	44.88 ± 0.93[ab]	3.64 ± 0.02[g]	3.27 ± 0.27[ab]
100 ppm Salicylic acid	11.18 ± 0.02[b]	11.06 ± 0.03[bc]	0.67 ± 0.00[bc]	0.67 ± 0.00[cde]	26.01 ± 0.03[a]	25.75 ± 0.03[b]	48.50 ± 0.51[ab]	47.83 ± 1.79[a]	3.82 ± 0.03[bc]	3.70 ± 0.27[ab]
200 ppm Salicylic acid	10.47 ± 0.02[g]	10.54 ± 0.03[e]	0.70 ± 0.00[ab]	0.70 ± 0.00[b]	25.27 ± 0.03[d]	23.75 ± 0.02[e]	45.71 ± 0.19 [cd]	42.07 ± 0.72[b]	3.63 ± 0.02[g]	3.23 ± 0.30[ab]
Control	10.46 ± 0.03[g]	10.43 ± 0.03[f]	0.72 ± 0.01[a]	0.73 ± 0.01[a]	24.80 ± 0.02[e]	23.48 ± 0.02[f]	44.27 ± 0.52 [d]	30.68 ± 0.81[c]	3.53 ± 0.02[h]	2.75 ± 0.15[b]
Mean	10.95	10.93	0.68	0.68	25.59	24.71	47.39	45.26	3.74	3.47
CD (P<0.05)	0.07	0.10	0.03	0.02	0.27	0.06	2.25	5.10	0.06	1.04

and due to the enhanced transport of sugars from source to the sink (Ahmed *et al.* 2008). As results, there is an enhanced mobilization of carbohydrates from their source to sink within plant in acid lime (Lakshmi *et al.* 2014). This increased permeability can potentially facilitate the breakdown of organic acids stored within cell vacuoles, ultimately resulting in the increase of total soluble solids. Similar results have been documented by Huang and Huang (2005) in citrus species and Nawaz *et al.* (2011) in Kinnow mandarin. Highest acidity percentage was recorded in control (0.72 and 0.73%) whereas the minimum acidity percentage was recorded in GA_3 at 10 ppm (0.65 and 0.66%) during 2021 and 2022, respectively followed by NAA at 20 ppm (0.67 and 0.66%). The reduction in fruit acidity could be attributed due to acceleration of orange maturation, leading to earlier ripening compared to untreated plants. Similar results were observed by Talat *et al.* (2020) in Kinnow mandarin.

Concentration of vitamin C content was different in all citrus species. Maximum ascorbic acid (26.06 and 25.83 mg/100 ml) was observed with GA_3 at 10 ppm, followed by NAA at 20 ppm (26.03 and 25.78 mg/100 ml), while the minimum ascorbic acid content was found in untreated plants (24.80 and 23.48 mg/100 ml) during 2021 and 2022 (Table 3). With the application of plant growth regulators (PGRs), the elevation in ascorbic acid content can be attributed to an increase in osmotic pressure resulting from cell expansion, which, in turn leads to the accumulation of organic acids. The vitamin C content in fruits exhibits variations depending on the citrus species and is influenced from environmental factors, the timing of fruit harvesting, plant vigour, plant age, and the use of PGRs. Similar results were observed by Sandhu and Bal (2013) in lemon and Hifny *et al.* (2017) on Washington Navel oranges. Maximum juice content (50.58 and 49.66%) was observed with application of GA_3 at 10 ppm, followed by NAA at 20 ppm (50.29 and 48.42%) during growing seasons 2021 and 2022 respectively (Table 3). The minimum juice percentage was recorded with untreated plants (44.27 and 30.68%). An increase in juice content of Daisy mandarin fruits were due to foliar application PGRs, by influencing various biochemical and physiological processes in plants. Nawaz *et al.* (2011) concluded that application of plant growth regulators led to a noteworthy enhancement in juice yield, while the untreated plants exhibited the lowest juice percentage. Similar results were observed by Singh and Kaur (2018), who reported that highest juice content was found with GA_3, in contrast, the untreated plants yield the lowest juice percentage.

Flavonoids can enhance the quality of fruits and juices by influencing their appearance, taste, and nutritional value. Maximum flavonoids content was found in GA_3 at 10 ppm (3.93 and 3.91 mg RE/g FW), followed by NAA at 20 ppm (3.85 and 3.78 mg RE/g FW) while the minimum content (3.53 and 2.75 mg RE/g FW) of flavonoids was recorded in untreated plants during growing seasons 2021 and 2022, respectively. Our results are corresponding to the similar results reported by Talat *et al.* (2020), wherein they reported that the foliar application of GA_3 resulted in increased total flavonoid content in Kinnow mandarin. Wax apple fruits treated with GA_3 had the maximum content of flavonoids, when compared to controls (Moneruzzaman *et al.* 2011).

In conclusion, the application of 100 ppm salicylic acid at the initiation of fruit splitting was found effective to reduce the severity of fruit splitting, thereby enhancing the fruit quality and improving the nutrient content in leaves. The application of 10 ppm GA_3 at different stages of growth demonstrated significant positive effects on various aspects of Daisy mandarin including increasing the number of fruits, fruit weight, fruit size, overall yield and fruit quality attributes including total soluble solids, acidity levels, ascorbic acid content and flavonoids content in juice. These findings suggest that judicious use of growth regulators, particularly, salicylic acid, GA_3 and NAA can be promising strategy to reduce the fruits splitting and enhancing the fruit quality of Daisy mandarin.

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